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IS/IEC 61241-2-3 (1994): Electrical Apparatus for use in the presence of combustible dust, Part 2: Test Methods ; Section 3 Method for determining minimum ignition engergy of dust/air mixtures [ETD 22: Electrical Apparatus for Explosive Atmosphere]

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भाग 2 परीक्षण पद्धतियाँ

अनुभाग 3 धूल/वायु मिश्रण की न्यूनतम प्रज्वलन उर्जा ज्ञात करने की पद्धति

Indian Standard

ELECTRICAL APPARATUS FOR USE IN THE PRESENCE OF COMBUSTIBLE DUST

PART 2 TEST METHODS

Section 3 Method for Determining Minimum Ignition Engergy of Dust/Air Mixtures

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Electrical Apparatus for Explosive Atmospheres Sectional Committee, ETD 22

NATIONAL FOREWORD

This Indian Standard (Part 2/Sec 3) which is identical with IEC 61241-2-3 : 1994 'Electrical apparatus for use in the presence of combustible dust — Part 2: Test methods — Section 3: Method for determining minimum ignition energy of dust/air mixtures' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Electrical Apparatus for Explosive Atmospheres Sectional Committee and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, references appear to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 50 (301) : 1983 International Electrotechnical Vocabulary — Chapter 301: General terms on measurements in electricity	IS 1885 (Part 80) : 1994 Electro technical vocabulary: Part 80 General terms on measurements in electricity	Identical
IEC 50 (302) : 1983 International Electrotechnical Vocabulary — Chapter 302: Electrical measuring instruments	IS 1885 (Part 81) : 1993 Electro technical vocabulary: Part 81 Electrical measuring instruments	do

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 50 (303) : 1983	International Electrotechnical Vocabulary — Chapter 303: Electronic measuring instruments
ISO 4225 : 1980	Air quality — General aspects — Vocabulary

Only the English language text has been retained while adopting it as an Indian Standard, and as such the page numbers given here are not the same as in the IEC Publication.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ELECTRICAL APPARATUS FOR USE IN THE PRESENCE OF COMBUSTIBLE DUST

PART 2 TEST METHODS

Section 3 Method for Determining Minimum Ignition Engergy of Dust/Air Mixtures

1 Scope

This section of IEC 1241-2 specifies a method of test to determine the minimum ignition energy of a dust/air mixture by an electrically generated high-voltage d.c. spark. This test method is intended to develop data to be used in deciding whether or not combustible dust/air mixtures are considered to be ignitable with respect to electrical discharge. It is intended that the dust be tested in a form (particle size, moisture content, etc.) representing conditions of actual use so that assessment of the hazard present can be made. Ignition energies determined by this method would be compared with ignition energies of other dusts to assess the relative hazard with regard to ignition by an electrical or electrostatic discharge, thereby permitting decisions to be made on the suitability of electrical apparatus for installation in areas where combustible dust is present.

The test method is not suitable for use with recognized explosives, gunpowder, dynamite, explosives which do not require oxygen for combustion; pyrophoric substances, or substances or mixtures of substances which may under some circumstances behave in a similar manner. Where any doubt exists about the existence of a hazard due to explosive properties, an indication may be obtained by placing a very small quantity of the dust in question on the heated surface of the apparatus described in section 1 of the IEC 1241-2-1, heated to 400 °C.

NOTE – Precautions should be taken to safeguard the health of personnel conducting the tests against the risk of fire, explosion and/or the effects, including toxic effects, of combustion. Compliance with this international standard does not itself confer immunity from legal obligations.

Annex B of this section includes guidance on the significance of minimum ignition energy with respect to electrostatic discharges.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 1241-2. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section of IEC 1241-2 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(301, 302, 303): 1983, *International Electrotechnical Vocabulary*

- *Chapter 301: General terms on measurements in electricity*
- *Chapter 302: Electrical measuring instruments*
- *Chapter 303: Electronic measuring instruments*

ISO 4225: 1980, *Air Quality - General aspects - Vocabulary*

1—40 BIS/ND/09

3 Definitions

For the purposes of this section of IEC 1241-2, the definitions in IEC 50(301, 302, 303) and also the following apply.

3.1 **dust**: Small solid particles that settle out under their own weight but that may remain suspended in air for some time.

NOTE – This definition includes what are defined in ISO 4225 as "dust" and "grit".

3.2 **combustible dust**: Dust that is ignitable in mixtures with air.

NOTES

1 Mixtures of combustible dust in air are ignitable only between certain concentration limits.

2 Combustible dusts are capable of being ignited by external ignition sources and will continue to burn at atmospheric temperatures but they will only spontaneously ignite above their minimum ignition temperatures.

3.3 **spark discharge**: Transient electric discharge which takes place between two conductors which are at different potentials. A spark is a discrete discharge that bridges the gap between the conductors in the form of a single ionization channel.

3.4 **minimum ignition energy (of a combustible dust/air mixture)**: Lowest energy of spark (as measured by the procedure in this standard) that is capable of igniting the most sensitive dust/air mixture with sustained combustion.

3.5 **ignition**: In the test, ignition is considered to have occurred when:

- a pressure rise of at least 0,2 bar above any pressure introduced by the igniting spark is measured in a closed vessel (e.g. 20 l sphere); or
- a flame which propagates at least 6 cm away from the spark position is observed in an open tube (e.g. Hartmann tube).

3.6 **ignition delay time**: Time between dispersion of the dust and the occurrence of the spark discharge.

4 Test apparatus

4.1 *Spark generation circuit*

Annex A describes some suitable forms of circuit, all of which shall have the following characteristics. What follows deals only with the circuit:

- inductance of discharge circuit: 1 mH to 2 mH except when the data is to be used for the assessment of electrostatic hazards when the inductance of the discharge circuit shall not exceed 25 µH;
- ohmic resistance of discharge circuit: as low as possible and not more than 5 Ω;
- electrode material: stainless steel, brass, copper or tungsten;
- electrode diameter and shape: 2,0 mm ± 0,5 mm. Electrodes with rounded tips can be used to reduce corona effects that can occur with pointed electrodes, and which may give incorrect values of spark energy. If pointed electrodes are used, corona effects should be carefully considered;

- electrode gap: 6 mm (minimum);
- capacitors: low-inductance type, resistant to surge current;
- capacitance of electrode arrangement: as low as possible;
- insulation resistance between electrodes: sufficiently high to prevent leakage currents.

NOTE – Typically, a minimum resistance between the electrodes of 10^{12} Ω is required for a minimum ignition energy of 1 mJ, and 10^{10} Ω for a minimum ignition energy of 100 mJ.

4.2 *Test vessel*

The recommended vessels are the 20 l sphere apparatus and the Hartmann tube. These vessels are described in references [6] and [7]*. Other vessels can be used, provided that the calibration requirements in 6.2 are met.

5 Test sample

Tests shall be performed on samples in a state of preparation corresponding to that found in practice under plant conditions.

Minimum ignition energy decreases with decreasing particle size. Tests shall be carried out on samples having particle sizes that are consistent with, or finer than, the finest material that can be present in the intended use.

For comparative tests the samples shall be prepared by a constant method with the object of fixing particle size distribution and moisture content.

NOTE – Where the particle sizes of the material are not known, tests should be carried out on particle sizes less than 63 µm.

Minimum ignition energy decreases with decreasing particle size. It should be checked that the particle sizes of the sample are representative of the finest material that can be present in the plant. Tests should be carried out on material of particle size less than 63 µm.

6 Procedure

6.1 *Brief description*

The combustible dust to be tested is uniformly dispersed in air at atmospheric pressure and temperature in a suitable apparatus, and the dust/air mixture is subjected to a spark discharge from a charged capacitor.

The energy value of the discharge is calculated from the formula:

$$W = 0{,}5\ C \times U^2$$

where

W is the stored energy in joules (J);

C is the total discharge capacitance, in farads (F);

U is the voltage of the charged capacitor in volts (V).

---

* Figures in square brackets refer to the bibliography, annex C

NOTES

1 At spark energies above 100 mJ, the spark resistance can become so small that the circuit resistance is no longer negligible compared with the spark resistance, particularly when the circuit contains an inductance coil of the order of 1 mH. In such cases the net spark energy can be obtained from the equation:

$$W = \int I(t)\, U(t)\, dt$$

where

$I(t)$ is the spark current, and

$U(t)$ the spark voltage, both of which are obtained by measurement.

2 Further information relative to the calculation of spark energies is contained in annex A.

It is necessary to take account of the following possible influences on the test:

- dust/air mixture aerodynamics (e.g. ignition delay time, dispersing pressure);
- dust concentration;
- voltage to which the capacitor is charged;
- capacitance of the capacitor;
- inductance of the discharge circuit;
- ohmic resistance of the discharge circuit;
- materials and dimensions of the electrodes and the gap between the electrodes.

To limit the expense of testing, every apparatus uses electrodes composed of a specific material with standardized dimensions and minimum electrode gap. The ohmic resistance of the discharge circuit shall be kept as low as possible (see clause 4).

Starting with a spark energy that will reliably cause ignition of the dust being tested, the dust concentration and dust dispersion parameters (e.g. ignition delay time and dispersion pressure) are adjusted to establish the most ignitable dust cloud. Using the optimal conditions for ignition, the spark energy is successively halved, by adjusting the capacitance of the capacitor and/or the voltage to which it is charged, until no ignition occurs in 20 successive tests.

NOTE – When tests are carried out using the 20 l sphere apparatus, the ignition delay time should be 120 ms.

The minimum ignition energy, W_{min}, lies between the highest energy, W_1, at which ignition fails to occur in 20 successive attempts to ignite the dust/air mixture, and the lowest energy, W_2, at which ignition occurs within 20 successive attempts.

$$W_1 < W_{min} < W_2$$

6.2 *Calibration*

Calibration tests should be carried out on three reference dusts which shall have been dried under atmospheric pressure at 50 °C for 24 h prior to the measurements.

The results shall be within the following ranges:

lycopodium:	W_{min} = 5 to 15 mJ, mean particle diameter 31 µm;
anthraquinone:	W_{min} = 2 to 6 mJ, mean particle diameter 18 µm;
polyacrylonitrile:	W_{min} = 2 to 6 mJ, mean particle diameter 27 µm.

The dust dispersion parameters, including ignition delay time, for each sample shall be noted.

6.3 *Test report*

Where the test has been carried out in accordance with this standard, the test report shall provide the information listed in 6.3.1, 6.3.2 and 6.3.3. Although the dust concentration values associated with the limits of the range of minimum ignition energy should be recorded by the test laboratory, the values, expressed in terms of the amount of dust which is weighed, divided by the volume of the explosion vessel, are not usually included in the test report.

6.3.1 *Product characteristics*

- sample designation (name and chemical description if not implicit in the name);
- sample origin or source;
- sample pre-treatment;
- characteristics data for particle size distribution and moisture content if available and not already given by pre-treatment procedures.

6.3.2 *Characteristics of the test apparatus*

- triggering;
- explosion vessel;
- dust-dispersion system;
- total inductance of the discharge circuit;
- charging voltage, electrode material and length of gap of the optimized discharge circuit.

6.3.3 *Results*

- highest energy W_1 at which ignition does not occur;
- lowest energy W_2 at which ignition is obtained.

6.3.4 *Report form*

An example of a suitable form is given in figure A.1.

Annex A
(informative)

Examples of spark-generating systems

A.1 General

Clauses A.2, A.3, A.4 and A.5 contain descriptions of four designs of spark-generating circuit suitable for use in this test. With any of these examples it is possible to use different explosion vessels, provided that the dust dispersion is optimized and that suitable precautions are taken in order to prevent side-effects occurring in comparatively large vessels from electrostatic charging phenomena during the dispersion of the dust. These phenomena include additional charging/discharging of the capacitor.

If the storage capacitor is decoupled from the electrode during the charging process, the effect of the decrease in voltage that will occur due to the increase in capacitance when the connection to the electrode is made, should be taken into account in calculating the spark energy. In all calculations of energy the total capacitance of the discharge circuit should be used, and the voltage at the time of discharge.

A.2 Triggering by auxiliary spark using three-electrode system

Figure A.2 illustrates the general arrangement of the test apparatus.

The essential component is a three-electrode spark gap. The two electrodes forming the main spark gap (1) are 3,2 mm in diameter, their ends being reduced to a diameter of 2,0 mm over a length of 20 mm. The free end of the auxiliary electrode (2) is angled toward the main spark gap, the length of this angled portion being 20 mm. This electrode arrangement is installed in an open-top Hartmann tube and is also suitable for installation in other explosion vessels.

Following the introduction into the mixture-generating device of the desired quantity of dust, the tube is placed in position. The test capacitor C (20 pF to 10 000 pF), which stores the ignition energy, is charged by means of the high-voltage charging unit HVCU across the charging resistance *R* which limits the charging current to 1 mA. The attempts to ignite the dust/air mixture are initiated by means of the control facility CF. Initiation of each attempt involves, first of all, triggering the device which disperses the dust into suspension, followed, after a predetermined interval, by the auxiliary spark and, with it, the triggering of the main spark discharge by the test capacitor.

The energy of the auxiliary circuit is limited to not more than one-tenth of the energy of the main discharging circuit.

A.3 Triggering by electrode movement

Figure A.3 illustrates the general arrangement of the test apparatus.

PTFE stoppers (2) are fitted into the two electrode mounting ports in an open-top Hartmann tube (1). These stoppers are bored in order to receive the electrodes (3) in a manner permitting them to be moved. One of the electrodes, which is at earth potential, is attached to the measuring rod of a micrometer screw (4). The yoke of the micrometer is shortened, and is fastened to the modified Hartmann tube. The other electrode, to which the high voltage is applied, is attached to the pushrod of a controllable, double-acting pneumatic piston (6) (piston nominal diameter: 35 mm; operating pressure: 600 kPa) which has a working travel of 10 mm, attachment being through a PFTE insulating piece (5). The high-voltage electrode is electrically connected to a capacitor (7) with a value between 26 pF and 311 μF. The voltage to which this capacitor is charged is indicated by means of an electrostatic voltmeter (8). After disconnecting the high-voltage generator (9) from the capacitor circuit, air is released electro-pneumatically from the pressure vessel (10) in which it is stored under pressure in such a way as to form a dust/air mixture by dispersing the dust in suspension. After a delay, which is set with the aid of a timing device (11), the high-voltage electrode is shot into the position defining the spark-gap length, the energy stored in the capacitor then being liberated at the spark gap.

A.4 Triggering by voltage increase (trickle-charging circuit)

Figure A.4 illustrates the general arrangement of the test apparatus.

The trickle-charging circuit is one of the simplest methods for producing sparks of known energy which are required for determining the minimum ignition energy of dust/air mixtures.

A high-voltage d.c. supply slowly raises the potential of the capacitor until a spark occurs. The cycle is then repeated, giving a series of sparks, each of the same energy. A current limiting resistor with a value between 10^8 Ω and 10^9 Ω is included in the circuit. The potential across the capacitor is measured by an electrostatic voltmeter with a decoupling resistor in series having a value between 10^8 Ω and 10^9 Ω. Sparks of any energy level from 1 mJ upwards can be readily produced using this circuit by varying the value of the capacitor and, if necessary, the discharge voltage.

The settings for sparks of the required energy are determined before any dust is placed in the ignition chamber. A capacitor of the appropriate value is chosen and a voltage in the range 10 kV to 30 kV selected. The voltage and electrode separation are then adjusted by trial until sparks of the required energy, given by 0,5 CU^2 occur at the electrodes. In this expression, U is the voltage at which the spark occurs and C is the total capacitance at the high-voltage electrode, which can be measured using normal a.c. bridge methods. In order to make an ignition test, the high-voltage electrode is earthed and the required quantity of the prepared dust is placed in the dispersion cup. The d.c. voltage supply is then switched into the circuit, and, as sparks start to pass between the electrodes, the dust is dispersed by an air jet. It is noted whether ignition occurs and whether the flame propagates away from the spark gap.

The first tests are usually performed with a high-spark energy typically 500 mJ. If there is an ignition, the spark energy is then reduced in steps, and the test repeated until ignition does not occur, as described in 6.1.

A.5 Triggering by auxiliary spark, using normal two-electrode system (trigger transformer in discharge circuit)

Figure A.5 illustrates the general arrangement of the test apparatus.

This circuit cannot be used for tests without inductance. *C* is the discharge capacitor, having an initial voltage of *U*. By having a range of capacitors from 40 pF and downwards in steps of a factor of 10, and variable voltage from 1 000 V downwards (400 V to 500 V is a practical minimum level), a wide selection of 0,5 CU^2 values is available. Initiation of spark discharge at the desired moment, which is essential if synchronization of spark discharge with the formation of a transient dust cloud is required, is accomplished by means of the trigger circuit in which the capacitor C_{Tr}, a switch S, and the primary coil of the trigger transformer T constitute the essential elements. By closing the switch, a high-voltage pulse of approximately 15 kV peak value is induced in the secondary coil of the transformer, causing breakdown of the spark gap G, and thereby discharge of the main capacitor C. Experience has shown that it is very difficult to reduce the energy input to the spark gap by the trigger spark below 2 mJ to 5 mJ. For this reason, this trigger principle is only applicable to spark energies above 5 mJ

The net spark energies generated for various combinations of C and U are determined in the conventional way by measuring current and voltage at the spark gap as functions of time and integrating the power-versus-time curve. The function of the diode D is to produce unidirectional discharges only. The self-inductance of the secondary coil of the trigger transformer should be 1 mH to 2 mH.

Minimum ignition energy of a dust/air mixture measured according to IEC 1241-2-3

1) *Product characteristics*

sample designation: . . . .

sample origin or source: . . . .

sample pre-treatment: . . . .

particle size information . . . .
(e.g. median, range, maximum)

moisture content . . . .

2) *Test apparatus*

triggering: . . . .

explosion vessel . . . .

dust dispersion system: . . . .

total inductance: . . . .

electrode gap: . . . .

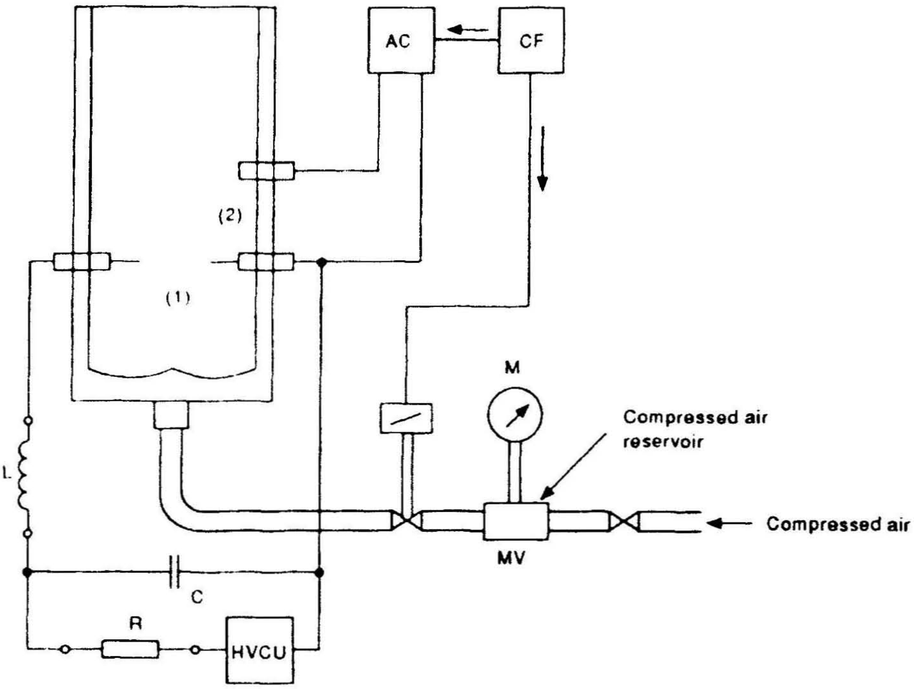
charging voltage . . . .

Result:

$< W_{min} <$

Date: . . . . Signature: . . .

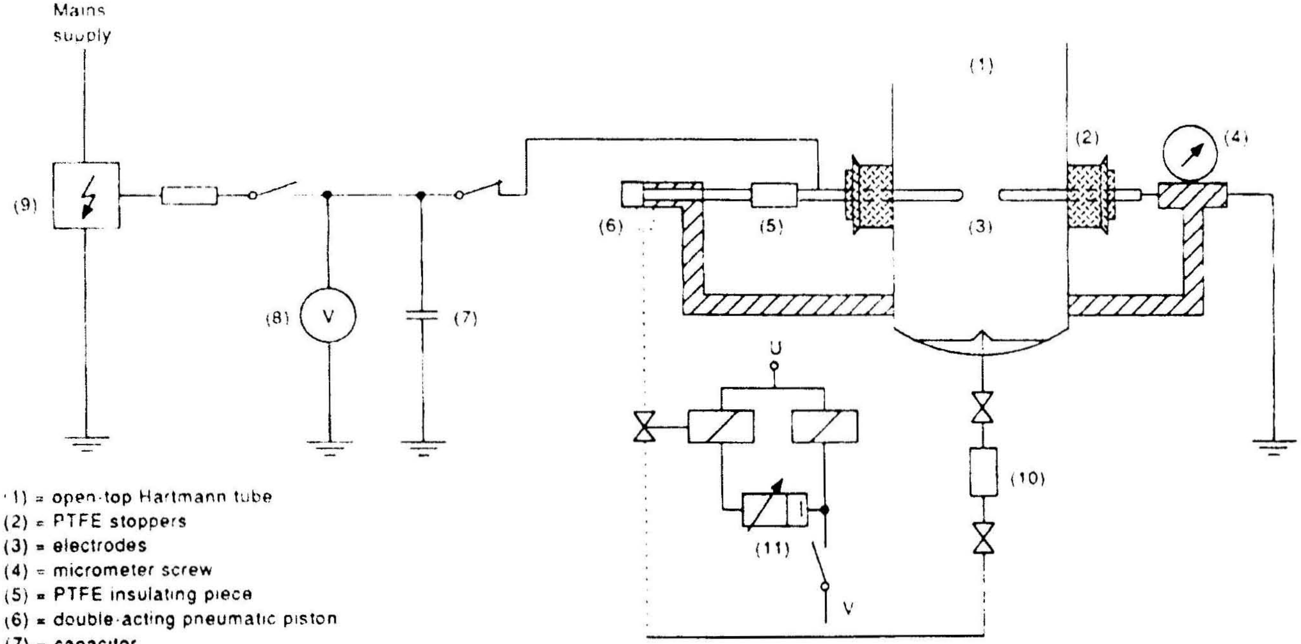
Figure A.1 – Specimen report form



AC = auxiliary circuit
CF = control facility
M = manometer
MV = magnetic valve
V = shut off valve

C = test capacitor
HVCU = charging unit
L = inductance
R = charging resistance

Figure A.2 – Apparatus for determining the minimum ignition energies of dust (schematic) – Triggering by auxiliary spark, using three-electrode system



(1) = open-top Hartmann tube
(2) = PTFE stoppers
(3) = electrodes
(4) = micrometer screw
(5) = PTFE insulating piece
(6) = double-acting pneumatic piston
(7) = capacitor
(8) = electrostatic voltmeter
(9) = high-voltage generator (5 to 10 KV)
(10) = pressure vessel
(11) = timing device

Figure A.3 – Apparatus for determining the minimum ignition energies of dust (schematic) – Triggering by electrode movement

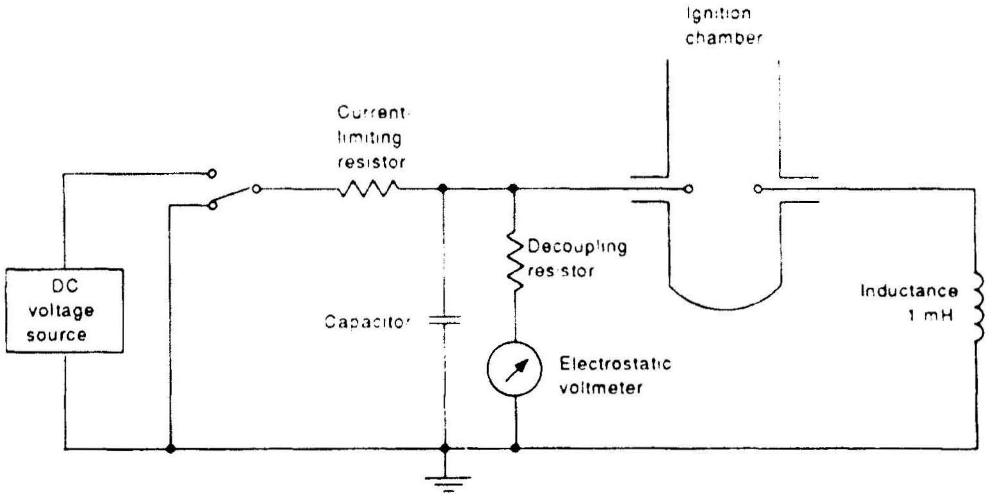
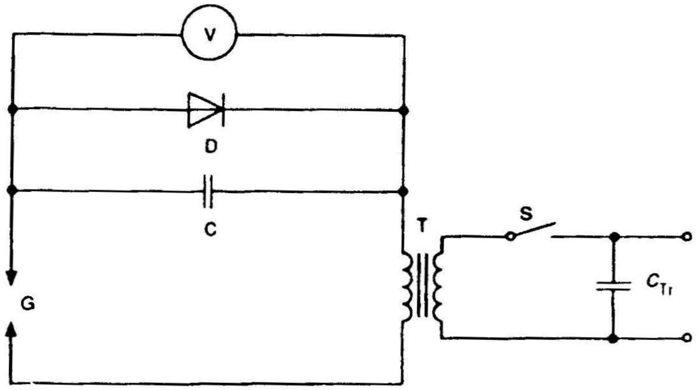


Figure A.4 – Apparatus for determining the minimum ignition energies of dust (schematic) – Triggering by voltage increase



C = main capacitor
C_{Tr} = capacitor in trigger circuit
D = diode
S = switch
T = transformer
G = spark gap

Figure A.5 – Apparatus for determining the minimum ignition energies for dust (schematic) – Trigger transformer in discharge circit

Annex B
(informative)

Significance of minimum ignition energy

Although it is not within the scope of this standard to specify limits or safety precautions as functions of the measured minimum ignition energies, it is appropriate to give some guidance on the significance of the measured values in relation to the safety of industrial installations.

Several discharge types need to be considered. These are:

– glow corona	from pointed or small radius conductors
– brush	from bulk powder or insulating solids
– cone	from highly insulating granules
– propagating brush	from polarized insulating surfaces
– spark	

Detailed descriptions of these discharges, and their occurrence can be found in the literature [11]. Their ignition capabilities are indicated in the table below in relation to minimum ignition energies measured by the present method.

Table B.1 – Ignition capabilities of various types of electrostatic discharge

Discharge type	Ignition capability	Minimum ignition energy mJ
Corona	Ignition of dust clouds other than explosives not likely	Up to 0,1
Brush	Hybrid mixtures and some very sensitive dusts may be ignited	Up to 3
Cone	Most combustible dusts may be ignited	Increase with volume of material
Propagating	Most combustible dusts may be ignited	Typically up to several joules
Sparks	Any combustible dust may be ignited	No limit

Sparks are the most potent type of electrostatic discharge, and are capable of igniting a wide range of flammable mixtures. The basic precaution against the occurrence of incendive spark discharges is to ensure that all conducting parts of the plant and equipment and conductive products are securely earthed.

In order to give a wide margin of safety, and to allow for variations of resistance over a period of time, a resistance to earth of less than 10^8 Ω is advocated for conducting items.

The maximum safe electrical resistance (R) between a conducting part and earth can be determined from the maximum electrostatic charging current (I) in the system.

It is well established that spark discharges that occur at 100 V or less do not cause ignition primarily because the gap across which the spark passes is much smaller than the quenching distance.

Using Ohm's law and a maximum voltage of 100 V, the maximum safe resistance is given by:

$$R = \frac{100\ \mathrm{V}}{I}$$

The maximum charging current for most types of operations is 10^{-6} A so that the maximum safe resistance to earth in these cases is 1×10^8 Ω. In very energetic operations, charging currents may reach 10^{-4} A. In such instances the maximum safe resistance would be 1×10^6 Ω.

In cases where proper earthing cannot be achieved, the minimum ignition energy can be used to determine whether earthing is essential. From knowledge of the charging rate, the electrical capacitance, duration of operation and leakage resistance, it is possible to calculate the maximum amount of energy that can be stored. This can then be compared with the lowest minimum ignition energy from the materials handled in the plant. Alternatively, if the maximum potential that can occur is limited by a fixed, narrow gap across which any spark will pass (for example, in some rotating machinery such as rotary valves) similar calculations can be made and compared with the measured minimum ignition energy. In all these cases it is essential that the lowest minimum ignition energy from the materials being handled or processed is used in the comparisons.

The assessment and control of the other types of discharge require expert knowledge, but general guidance is available in the literature [11].

Spark discharges from charged, unearthed metal parts of plant and equipment are capacitative. To assess the ignition hazard in the case of such sparks, minimum ignition energy values can be determined by using a simple, plain capacitative discharge circuit. In some cases, the repeatability and reproducibility of results from such circuits can be improved by the inclusion of an inductance of 1 mH in the discharge circuit. It should be noted, however, that this modification normally produces more incendive sparks than a plain capacitative discharge circuit and, therefore, lower minimum ignition energy values. This can lead to the adoption of precautions that are not strictly necessary, with the attendant costs.

Experimental investigations on a great number of dusts, using ignition sources other than electric sparks, indicate that the ranking order of the ignitabilities of dust clouds, obtained by using the present test method for minimum ignition energy, is also valid for other types of ignition sources. Differences in the characteristics of energy release are responsible for the differences in the total amount of energy required for igniting a given mixture by various ignition sources. A well-known example of the problem of drawing conclusions based only on a comparison of total energies is the attempt to assess the incendivity of brush discharges in the case of dust clouds. Previous experiments have shown that brush discharges can ignite explosible gas mixtures of minimum spark ignition energies of 4 mJ. However, so far it has not been possible to demonstrate that dust clouds of considerably lower minimum electric spark ignition energies than 4 mJ can be ignited by brush discharges. One reason for this could be that in the case of brush discharges the discharge time is different.

Determination of absolute energies required for igniting dust clouds is possible as far as ignition by electric sparks is concerned; provided the measurement method satisfies the requirements stated earlier. In principle, the spatial and temporal distribution of the energy in the discharge constitutes the basic characteristic of the incendivity of any discharge. However, an equivalent energy can be ascribed to a discharge by equating it to the energy of a spark discharge that gives the same incendivity as the discharge being considered.

The problem of determining equivalent energies for mechanical sparks is discussed elsewhere [1] and [2].

The considerations above are only applicable to combustible dusts. When it comes to the incendivity of spark discharges in mixtures of a dust cloud and an explosible gas, the technical literature should be consulted [3], [4], [5], [6]. In case of doubt, the value for the gas alone should be used.

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